論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Study of ultrasonic velocity profiling method on boiling two-phase flow
著者(和文)	NGUYEN Tat Thang
Author(English)	NGUYEN Tat Thang
出典(和文)	学位:博士（工学）, 学位授与機関:東京工業大学, 報告番号:乙第4122号, 授与年月日:2016年2月29日, 学位の種別:論文博士, 審査員:木倉　宏成,竹下　健二,加藤　之貴,赤塚　洋,相樂　洋
Citation(English)	Degree:, Conferring organization: Tokyo Institute of Technology, Report number:乙第4122号, Conferred date:2016/2/29, Degree Type:Thesis doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

THESIS OUTLINE

Title: Study of Ultrasonic Velocity Profiling Method on Boiling Two-Phase Flow

Year: 2015

Author: Nguyen Tat Thang
Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology

Advisor: Associate Professor Hiroshige Kikura
Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology

Doctoral Dissertation Outline:

In the thesis, the study of ultrasonic velocity profiling method on boiling two-phase flow is presented. The main objective of the study is to develop new techniques for the measurement of boiling flow, specifically, of subcooled flow boiling. The thesis includes five chapters outlined below:

Chapter 1, "**Introduction**". This chapter presents the background of the thesis research. Boiling two-phase flow has long been acknowledged as one of the most efficient heat transfer mechanisms. The flow plays an essentially important role on the safe and optimal operation of the systems, particularly of water cooled nuclear power plants. However, two-phase flow is not fully understood due to its complexity. The accuracy of the numerical prediction of the flow behaviors is still limited. In the numerical simulation of two-phase flow, various closure models are widely used. Therefore experimentally measured data are strongly required for the development of closure models, validation of numerical models etc. Advanced numerical simulation, e.g. CFD simulation, requires high spatial/temporal experimental data of the distribution of two-phase flow parameters such as phase velocity, void fraction etc.

Measurement methods have been developed to measure two-phase flow. However, these methods still have limitations. Some are intrusive. Some require optical access into the flow field. Moreover, very few methods can measure velocity distribution. Among them, the ultrasonic velocity profile (UVP) method has been established as a powerful method to measure velocity distribution (i.e. velocity profile). The method has important advantages such as being non-intrusive; no requirement of any optical access into the flow field, being applicable to two-phase flow etc. Commercial UVP systems are available. However, their application to two-phase flow measurement has some difficulty as well as their cost is high. Custom UVP signal processings which are based on either the pulse repetition Doppler method (namely UDM) or the cross-correlation method (namely UTDC) have been developed. In UVP measurement, the concentration of ultrasonic reflectors is an important factor. So far suitable signal processing technique for a particular ultrasonic reflector (or particle) concentration has not yet been examined. In this study a new UVP signal processing technique based on the spike excitation (for ultrasonic emission) and auto-correlation pulsed Doppler method (for velocity calculation) is developed in Chapter 2. Spike-excitation Doppler UVP systems have advantages as well as are in-expensive. Comparative measurements and analyses by using UDM and UTDC signal processings have been carried out. The spike-excitation signal processing technique is applied to the development of a multiwave UVP method for two-phase flow measurement in Chapter 3. By using UVP method, a new method to measure the condensation rate in subcooled flow boiling is developed in Chapter 4.

Chapter 2, "**Development of a UVP method by using spike excitation and pulsed Doppler techniques**". This chapter presents the development of a new signal processing technique for the UVP method. The technique is based on the auto-correlation pulsed Doppler and the spike excitation techniques. The spike excitation is used instead of the tone-burst excitation which is widely used in the conventional UVP method. Spike pulser/receivers (P/R) are widely used in the ultrasonic testing. In addition, spike technique may enable high spatial-resolution measurements. Previously, it was not used with the pulsed Doppler method. The damping of the spike excitation is found to be the key to the successful application of the spike excitation to the measurement of velocity. In addition, the use of auto-correlation signal processing is essentially important. When the damping of the spike signal is low, pulsed Doppler UVP measurement of liquid flows is enabled by the auto-correlation signal processing.

Original signal processing software and hardware have been developed. And the spike-excitation auto-correlation pulsed Doppler UVP method (namely Spike_UDM) has been established. Validation of the method has been carried out by the measurements of vertical pipe flow. High accuracy of the measured data has been confirmed by comparison with the logarithmic law, PIV measured data and flowmeter data. In addition, comparative measurements by using UDM and UTDC signal processings have been carried out. It is found that the measurement length of UDM technique, which includes the Spike_UDM, is much larger than that of the UTDC technique.

Chapter 3, "**Development of a multiwave UVP method by using spike excitation and pulsed Doppler techniques for two-phase flow measurement**". This chapter describes the development of a multiwave UVP method for two-phase flow measurement by using Spike_UDM technique. The multiwave UVP method exploits a specially designed multiwave ultrasonic sensor which has two active piezoelectric elements. The 8 MHz element (3 mm diameter) has a cylindrical shape. It fits in the hollow of the 2 MHz element (10 mm diameter) which has a donut shape. The sensor is able to emit and receive the two frequencies at the same time along one line. Two synchronized spike P/Rs are used to control the two frequencies. The multiwave UVP method enabled simultaneous measurement of liquid- (by 8 MHz frequency) and bubble (by 2 MHz frequency) velocity profiles along one measurement line. However the multiwave UVP method has an inherent issue that bubble data are included in the data measured by 8 MHz frequency. Previous phase separation methods either have limitations or can not be applied to the Spike_UDM technique. Hence, a new phase separation technique is developed to discriminate the bubble data from the data measured by the 8 MHz frequency.

Original signal processing software and hardware have been developed. And the Spike_UDM multiwave UVP method has been established. Validation of the method has been carried out by the measurement of bubbly counter-current flow in a vertical pipe. The accuracy of the measured velocity profiles of liquid and bubble phases has been examined. The new phase separation technique has been applied. The performance of the technique has been discussed.

Chapter 4, "**Development of a new method to measure the condensation rate in subcooled flow boiling by using two ultrasonic frequencies**". In this chapter, the development of a new method to measure the condensation rate of vapor bubbles in subcooled flow boiling is presented. The condensation rate is an important parameter in both experimental and numerical simulations of boiling two-phase flow. It is defined as v_c=-dR/dt where R is the bubble radius and t is time. Bubbles are assumed to be spherical or the spherical equivalent bubble radius is used. The new method uses two simultaneous UVP measurements of the velocity of the bubble top- and bottom surfaces. The condensation rate is calculated by using the UVP measured data. The principle of the method is established.

Validation of the new method has been carried out. First, the velocity resolution of the UVP measurement is confirmed to be adequate for the measurement of the condensation effect on the bubble surface velocity. Next, the new method is validated by the measurement of an adiabatic air-water bubbly flow whose condensation rate is known to be zero. Finally, the method is applied to the measurement of a subcooled boiling column in a vertical pipe. The measured condensation rate is compared with that of the optical visualization and digital image processing. Acceptable agreements have been obtained in both cases.

Chapter 5, "**Conclusions**". Insights from the Chapter 2 to 4 are summarized in this chapter.